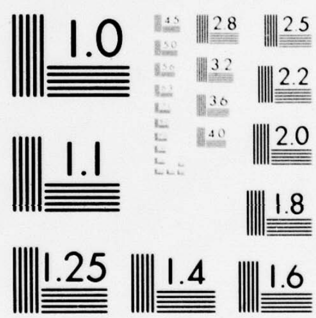
AD-A074 866 AEROSPACE MEDICAL RESEARCH LAB WRIGHT-PATTERSON AFB OH F/G 17/7
TIME SIMULATION OF AN AIR SURVEILLANCE TASK WITH VARYING AMOUNT--ETC(U)
JUN 72 W H PEARSON
UNCLASSIFIED AMRL-TR-72-74 NL

1 OF 1
AD A074 866

END
DATE
FILMED
11-79
DDC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

SECURITY CLASSIFICATION OF THIS PAGE (*When Data Entered*)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

3

14

1. REPORT NUMBER AMRL-TR-72-[redacted]74 ✓ per author	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (*and Subtitle*) 6 Time Simulation of An Air Surveillance Task with Varying Amounts of Radar Information.	5. TYPE OF REPORT & PERIOD COVERED 9 Technical Report.
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) William H. Pearson 10	8. CONTRACT OR GRANT NUMBER(s) LEVEL II
9. PERFORMING ORGANIZATION NAME AND ADDRESS Aerospace Medical Research Laboratory, Aerospace Medical Division, Air Force Systems Command, Wright Patterson AFB, OH 45433	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 62202F
11. CONTROLLING OFFICE NAME AND ADDRESS 12 27	12. REPORT DATE 11 Jun[redacted]972
	13. NUMBER OF PAGES 25
14. MONITORING AGENCY NAME & ADDRESS(*if different from Controlling Office*)	15. SECURITY CLASS. (*of this report*) Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (*of this Report*)

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (*of the abstract entered in Block 20, if different from Report*)

DDC

OCT 11 1979

A

18. SUPPLEMENTARY NOTES

*Manuscript submitted to Human Factors Journal.

19. KEY WORDS (*Continue on reverse side if necessary and identify by block number*)

Air Surveillance
Human Engineering
Radar
Time Compression
Man-Machine Relationships

20. ABSTRACT (*Continue on reverse side if necessary and identify by block number*)

Subjects observed a computer display unit simulating radar noise and radar trails of 150 and 500 mph aircraft, one per minute on the average, over a 1000 mile square area. Radar information was stored, cycle by cycle, up to a limit of 3, 5, 7 or 9 twenty second cycles and then presented sequentially rapidly enough to give an illusion of movement in the trails. Subjects detected the presence of aircraft and controlled computer processing by lightpen and keyboard actions. Time-to-detect

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

009 850 out

SECURITY CLASSIFICATION OF THIS PAGE (*When Data Entered*)

(20) increased with radar information for 500 mph tracks but not for 150 mph tracks. Probability of detection increased with radar information for 150 mph trails but not for 500 mph trails. These results were interpreted as showing the disruptive effect of (1) simulated radar noise confounded with the amount of radar information because of information storing and (2) the interference of the easier-to-find 500 mph aircraft with the 150 mph aircraft.

ACKNOWLEDGMENTS

The research reported in this paper was conducted by personnel of the Aerospace Medical Research Laboratory, Aerospace Medical Division, Air Force Systems Command, Wright-Patterson Air Force Base, Ohio. This paper has been identified by the Aerospace Medical Research Laboratory as AMRL-TR-72-74. Further reproduction is authorized to satisfy needs of the U.S. government.

INTRODUCTION

This is one of a series of experiments to determine the most effective radar trail length to use in an air surveillance task. An Air Surveillance Operator (ASO) in BUIC, Back-Up Interceptor Control, a back-up system in the Air Defense Command (Air Defense Command, 1967), monitors a radar display showing air traffic information. He monitors digitized raw radar data on a special display which portrays consolidated radar data from several radar installations. These raw radar data are divided into cycles, each cycle consisting roughly of the combined returns from one revolution of all radar antennae. Several cycles of raw radar data are stored and presented rapidly one after another in the order collected. Returns from an aircraft appear to form a trail and move across the display; returns from noise are random.

The task of the ASO is to discriminate between trails of sequential returns from aircraft and those from electronic noise. It is assumed that the noise rate per cycle is constant. The ASO informs the computer by button, switch, and lightpen action of the location, heading, and speed of a suspected aircraft; the computer then generates special symbols giving identifying information about the aircraft on the display. The symbols, together with the returns, are referred to as a <u>track</u>, and the above procedure is known as <u>Initiating</u> a track. The ASO also removes the special symbols from the display (<u>Drops</u> the track) when there are no radar returns

corresponding to the symbol and Reinitiates the track when no radar returns momentarily correspond with the symbols.

The intent of this experiment was not to reproduce the BUIC tasks exactly in a real-time fashion because the computer complex which was used as the simulation vehicle for this experiment did not have all of the switches, equipment, and design features of the BUIC III system. The intent, however, was to construct a general simulation environment for air surveillance studies. Normally, air surveillance systems will have equipment and tasks which would be prohibitively expensive to simulate in an on-line, real-time mode. This experiment attempted to simulate those tasks by a computer simulation model and to mix them mathematically with those tasks which could be simulated on-line in real time. Therefore, every time the subject wished to perform a task involving switches, equipment, or design features peculiar to the BUIC task and not physically present on the simulator he indicated this by special push-button action. This action, in turn, generated a task time by the Siegel-Wolf model (Siegel and Wolf, 1963). The Siegel-Wolf model is a computer program for generating a sample time for a task by a Monte-Carlo method. When task equipment is in the planning stage, being developed, or not physically present, the Siegel-Wolf model can generate realistic task times on that equipment. The Siegel-Wolf model takes the subtasks, their order of performance, their times, the variability of subtask times, their probability of success,

and other information and computes a sample performance time for the task in a BUIC mission. A master clock, unseen by the subject, controlled timing in the experiment and registered elapsed time except when the subject indicated a BUIC task should be performed. At that moment the master clock was incremented by a sample time calculated by the Siegel-Wolf model. The component subtasks and their sequence of performance have been taken from the BUIC training manuals. Realistic subtask times and variabilities, etc. were defined on the basis of stop-watch timing of actual operators. This experiment simulates a situation in which the ASO performs only Initiating, Dropping, and Reinitiating.

One important constraint upon the ASO is the time between successive activations of a computer switch or button and when the computer processes his information or request for action; only once per <u>computer data cycle</u> can the computer respond to him. A computer data cycle is the time between computer queries to the same operator or function; the computer queries, in turn, every other operator and function in the BUIC complex before it returns to the same operator or function. The time for a computer data cycle varies depending upon the computational load determined by the radar environment but has artificially been set at 20 seconds for this experiment. The Siegel-Wolf model, by incrementing the master clock with a sample time including computer data cycle time and thus decreasing total time available, simulates what the author

considers to be the most important feature of the task, the inability of the system to respond to any specific operator more than once per computer data cycle. The response time of the computer system is thus degraded and the simulated system reflects this limitation.

In this experiment radar trail length and aircraft speed were varied in a factorial design. Four levels of radar trail length were used; radar data from the latest cycle plus the previous 2, 4, 6, or 8 cycles were stored and presented at a rate of approximately 30 presentations of all data per minute. This procedure produces radar trails with 3, 5, 7, or 9 radar returns in them. Thus it may be seen trail length is equivalent to amount of radar information. These numbers cover the range of practical values. The constant electronic noise rate was arbitrarily represented by 19 radar returns per cycle. Two speeds of aircraft were used, 150 and 500 mph. The separate radar returns from a 150 mph track were not distinguishable, being only .012 inches apart on the display. The separate returns from a 500 mph track were easily distinguishable, being .036 inches apart. These two speeds were chosen because it was felt detectability would vary with separation of points.

METHOD

Equipment

The equipment used was the Human Engineering Systems Simulator with an IBM 360/40 computer and four 2250 Display Units

Model 3 serving as the simulator; only two of the display units were used for this study -- one for the experimenter and one for the subject. The CRT of this model has a twelve inch square usable display area and a lightpen. The P7 phosphor has a bluish initial color when activated and yellow-green persistence with a decay time to ten percent in the half second range. The display is refreshed 40 times per second. Thirty-one program function keys (PFK) and the lightpen can be used to generate interrupts and control branching within the computer program. Each IBM 2250 has an alarm soundable by the program.

Display

The subject sat in a dark room (.028 foot-candles illumination) as is normal in surveillance work and saw on the CRT a representation of Lake Superior, neighboring portions of other Great Lakes, the U.S.-Canadian Border plus a line bordering the displayed area, the whole display being centered approximately around Minneapolis, Minnesota, and representing a 1000 mile square area. See Figure 1. The illumination from the screen was significantly greater than the dark surround to give good contrast.

Raw radar returns only, represented by a "-" as in BUIC, appeared initially upon the CRT, every cycle containing 19 noise returns plus one or more returns from a simulated aircraft. After a track had been initiated, new returns for that track no longer appeared on the display described above but appeared on another

display (the Initiated Track Display generated on the same CRT) with the same background but with the initiated track represented by a "+" to differentiate among types of returns. This same display also appeared on the experimenter's CRT. The two displays were mutually exclusive but the subject could shift from one to the other at will by pressing one of the PFK's. Because the returns of several cycles are consolidated, level of noise is confounded with radar trail length as it would be if different numbers of cycles of radar information were stored on real radar displays. The amount of simulated electronic noise for the four levels of radar trail length in order are .~~136~~ 396, .~~272~~ .660, .~~408~~ .924, and ~~.544~~ 1,188 returns per square inch.

Scenario

Five different 30 minute scenarios were created, one for training and four for experimental conditions, with 90 updates of the display. An update is an addition to the display of radar data collected during a new cycle. A cycle took 20 seconds in this experiment. The training scenario consisted of simulated radar returns for noise plus twenty 500 mph tracks and ten 150 mph tracks all of which were presented by the twentieth update. Each of the four experimental scenarios consisted of simulated radar returns for noise plus fifteen 150 mph aircraft and fifteen 500 mph aircraft tracks. The tracks consisted of potential enemy aircraft flying in the northern U.S. and Canada.

The initiation of one track can interfere with the initiation of another track which appears on the CRT shortly after it in time. Each initiation takes a cycle to perform. Therefore, if during a cycle, a track were initiated, the subject cannot accomplish any other task during that cycle. Therefore the time intervals between the tracks in their order of appearance were identical across all experimental conditions to minimize effects due to differential interference. Mills and Bauer, 1970, refer to the track introduction rate used as a variable introduction rate.

Control Actions

In the experiment the subject was required to utilize lightpen and PFK's to indicate certain BUIC control actions, a sample time for which was generated by the computerized Siegel-Wolf model (Siegel and Wolf, 1963). These control actions are described below.

Initiate. When the subject found a configuration of radar returns he thought was a track, he would activate the PFK labeled "Initiate" and lightpen the appropriate return. The computer would stop presenting the track as a "-" on the raw radar returns display and start presenting the track as a "+" on the initiated track display with a short vector showing the track's heading. If the subject initiated a noise radar return, a "+" would appear on the initiated track display with an abnormally long vector associated that did not consistently indicate the same heading.

Drop. When the subject decided that the track had been initiated for approximately four minutes, he would push the PFK labeled "Drop" and lightpen that known track. The computer would then cease presenting any further returns belonging to that track.

Deinitiate. To simulate the computer's being unable to follow the track, the Experimenter had a PFK labeled "Deinitiate" at his own console. In each experimental session the experimenter picked randomly one track from every six tracks the subject initiated and by lightpen and program action changed them from "+" on the initiated track display to "-" on the raw radar return display.

Reinitiate. When the subject decided that the computer was unable to follow a track and the track had been lost, he and the computer would follow exactly the same procedure as for Initiate except that he would activate the PFK labeled "Reinitiate".

Track Display Status. If the subject wished to look at the initiated track display to drop a track or to determine whether or not any tracks had changed from "+" to "-", he would push the PFK marked "Track Display Status". The computer would then change the display from raw radar returns to initiated tracks. Another push of the "Track Display Status" PFK would change the display back.

Subjects

The subjects were 20 male college students, 18 to 24 years of age, from the University of Dayton, Dayton, Ohio. A significant

proportion of the personnel at an operational site appeared to fall into this age range. All stated they had 20/20 vision corrected and normal peripheral vision.

Procedure

In the training trial each subject was shown an example of a 150 and 500 mph track, shown all control actions he could take, and given 45 minutes experience training on the task. In all sessions the subject was instructed to (1) find all valid aircraft tracks as rapidly and accurately as possible, (2) make sure the computer did not lose any tracks, and (3) drop each track after approximately 4 minutes display. The intent of the Drop action was to create a light workload; it was not necessary for the subject to take 4 minutes exactly. Subjects were instructed to tell the experimenter immediately if they had initiated a noise radar return; the experimenter then deinitiated the track. In this manner the noise load on the display was kept uniform. Subjects were instructed to drop three tracks immediately if they heard their alarm sound; this simulates a dangerously high workload. The alarm sounded if more than 15 tracks would be present on the initiated track display. Order of the conditions was partially counterbalanced on level of radar trail length with each of the four levels occurring equally often on each of the four experimental days.

RESULTS

Track initiation times, the time between when a track first appeared and when it was initiated, were not significantly different for 150 mph tracks over levels of radar trail length. Track initiation times for 500 mph tracks were significantly different as tested by analysis of variance across levels of radar trail length ($p < .02$). See Figure 2. Probability of detection was significantly different

- -

Insert Figure 2 and Table 1 about here

- -

across levels of radar trail length for 150 mph tracks as tested by analysis of variance ($.05 > p > .01$) but was not significantly different for 500 mph tracks. See Figure 3. Track initiation times for the

- -

Insert Figure 3 and Table 2 about here

- -

two most quickly initiated tracks in each condition are significantly different as tested by analysis of variance across the two levels of aircraft speed ($p < .01$) and across levels of radar trail length ($.05 > p > .01$). The interaction between aircraft speed and radar trail length is nonsignificant. See Figure 4.

- -

Insert Figure 4 and Table 3 about here

- -

Practice effects were evaluated by analyzing the track initiation times across the order each subject received the various conditions in the experiment. Track initiation times of 150 mph tracks decreased significantly across order in the experiment as tested by analysis of variance ($.05 > p > .01$) but were nonsignificant for 500 mph tracks. See Figure 5.

- -

Insert Figure 5 and Table 4 about here

- -

Errors, defined as attempts to initiate a track where no aircraft existed, were not significantly different across levels of radar trail length or aircraft velocity. There were no significant differences across these variables for number of Drops, Reinitiates, or Track Display Status changes.

DISCUSSION

One of the basic variables for systems which deal with enemy aircraft is probability of detection - whether or not the aircraft can be detected by some means early enough to take effective countermeasures against it. The results of this experiment are interpreted

to mean that the level of radar trail length desired is related to the type of aircraft one expects to detect. If one is interested in detecting slow (150 mph) aircraft he would use a trail length of seven; probability of detection of 150 mph aircraft is greatest at 7 cycles. If he is interested in detecting faster (500 mph) aircraft, no specific trail length is indicated; probability of detection is not significantly different across cycles.

Track initiation times tell a different story. Track initiation times for 500 mph aircraft rise steadily across cycles of radar trail length while those for 150 mph aircraft remain more or less constant. These findings would indicate using three returns for 500 mph aircraft and any number for 150 mph aircraft and appear to contradict the recommendations of the paragraph above. However, observe Figure 3 for the total tracks initiated line. Between 7 and 9 radar returns per track, the probability of detection decreases; this is coincident with an increase in average track initiation time to a value greater than approximately 270 seconds. In a previous study (Pearson, 1971) a decrease in probability of detection on the same task was also noticed when the average overall track initiation time was greater than 270 seconds (appx.). These results may be interpreted in the following manner. Five hundred mph tracks, being easier to find relative to 150 mph tracks, are found more quickly in larger numbers and contribute more to total initiation time. When the average track initiation time exceeds 270 seconds (appx.) there

is no longer time to accomplish all the necessary processing and probability of detection decreases. A time of 270 seconds is appropriate to this study; in general it would be specific to the task.

Why should track initiation time increase with more radar returns per track? One might suspect the subjects are waiting to get all the information they can; after they realize the track is complete, they initiate it. This is not the case, however. If one looks at Figure 4 he can see that for 7 and 9 radar returns per track with 20 seconds per update, the subject is not waiting for a complete track but is initiating tracks as soon as he realizes they are tracks, less than 7 x 20 = 140 seconds. The interaction between radar trail length and aircraft speed is not significant; apparently 150 and 500 mph tracks are equally affected by whatever causes the increase. The reason that Figure 3 does not show this trend is that the 500 mph tracks being easier to find, interfere with initiation of the 150 mph tracks. Several tracks may be on the display at the same time and the subject will initiate the 500 mph tracks first.

It is hypothesized that the increase in track initiation times occurs because of the effects of electronic noise. The amount of electronic noise is constant per cycle but electronic noise is, of necessity, confounded with radar trail length; the more radar information is stored and presented, the more noise is stored and presented. As more noise accumulates on the display, it becomes

more difficult to discriminate between the noise and the tracks, and thus track initiation times increase with radar trail length.

It should be noted that the effects described above occurred with a very long computer data cycle, giving the subject fewer opportunities to respond in a fixed period of time. In addition, the computer program did not respond immediately after the subject made a response but artificially added time within that cycle, further decreasing the subject's ability to respond. Nevertheless, the variables of radar trail length and aircraft speed appear to affect aircraft initiation even under the above conditions and thus should be considered when designing air surveillance systems.

CONCLUSIONS

If detection of aircraft radar trails where the separate returns are distinguishable is desired, three radar returns per trail seem to be sufficient. If, however, detection of trails where the returns are very close together (much slower aircraft, relatively) is desired, seven returns per trail appear to be optimum. Perhaps the best design scheme would be one where the operator can vary radar trail length and thus trade-off between amount of radar information and amount of noise on the display. A sufficiently wide range of conditions has not been investigated to allow wide generalizability of these results.

REFERENCES

Air Defense Command. Radar inputs and countermeasures officer/ air surveillance, air surveillance technician. Air Defense Command Manual ADCBPH 55-64, 1967.

Lindquist, E. F. Design and analysis of experiments in psychology and education. Boston: Houghton, Mifflin, 1953.

Mills, R. G. and Bauer, M. A. Aircraft track initiation and maintenance in a single-operator simulated surveillance system. USAF: AMRL TR 70-103, 1971.

Pearson, W. H. The amount of radar time-history required for track initiation by air surveillance operators. USAF: AMRL TR (in preparation).

Siegel, A. I. and Wolf, J. J. Modification and further evaluation of a digital man-machine simulation model. ONR Contract Nonr-2492(00), Applied Psychological Services, Wayne, Pa., 1963.

TABLE 1

Analysis of Variance of Track Initiation Time

Source of Variance	df	MS	F
	150 mph Aircraft Trails		
Returns in Trail	3	.41	.46
Subjects	15	3.08	
Error	45	.90	
Total	63		
	500 mph Aircraft Trails		
Returns in Trail	3	2.80	5.09*
Subjects	15	.93	
Error	45	.55	
Total	63		

*$p < .02$

TABLE 2

Analysis of Variance of Probability of Detection of Aircraft

Source of Variance	df	MS	F
150 mph Aircraft Trails			
Returns in Trail	3	15.29	3.35*
Subjects	15	19.08	
Error	45	4.57	
Total	63		
500 mph Aircraft Trails			
Returns in Trail	3	1.39	.51
Subjects	15	5.87	
Error	45	2.71	
Total	63		

*$.05 > p > .01$

TABLE 3

Analysis of Variance of Two Most Quickly Initiated Tracks by Aircraft Speed and Number of Returns in Trail

Source of Variance	df	MS	F
Aircraft Velocity (V)	1	27,295.19	13.88*
Number of Returns (R)	3	14,380.65	4.85**
Subjects (S)	15	86,371.74	
V X R	3	670.05	.26
V X S	15	1,966.39	
R X S	45	2,964.44	
V X R X S	45	2,591.82	
Error	128	1,438.88	
Total	255		

*$p < .01$

**$.05 > p > .01$

TABLE 4

Track Initiation Times as a Function of Practice

Source of Variance	df	MS	F
	150 mph Aircraft Trails		
Trials	3	2.96	4.05*
Subjects	15	3.08	
Error	45	.73	
Total	63		
	500 mph Aircraft Trails		
Trials	3	.64	.93
Subjects	15	.93	
Error	45	.69	
Total	63		

*$p < .01$

LIST OF FIGURES

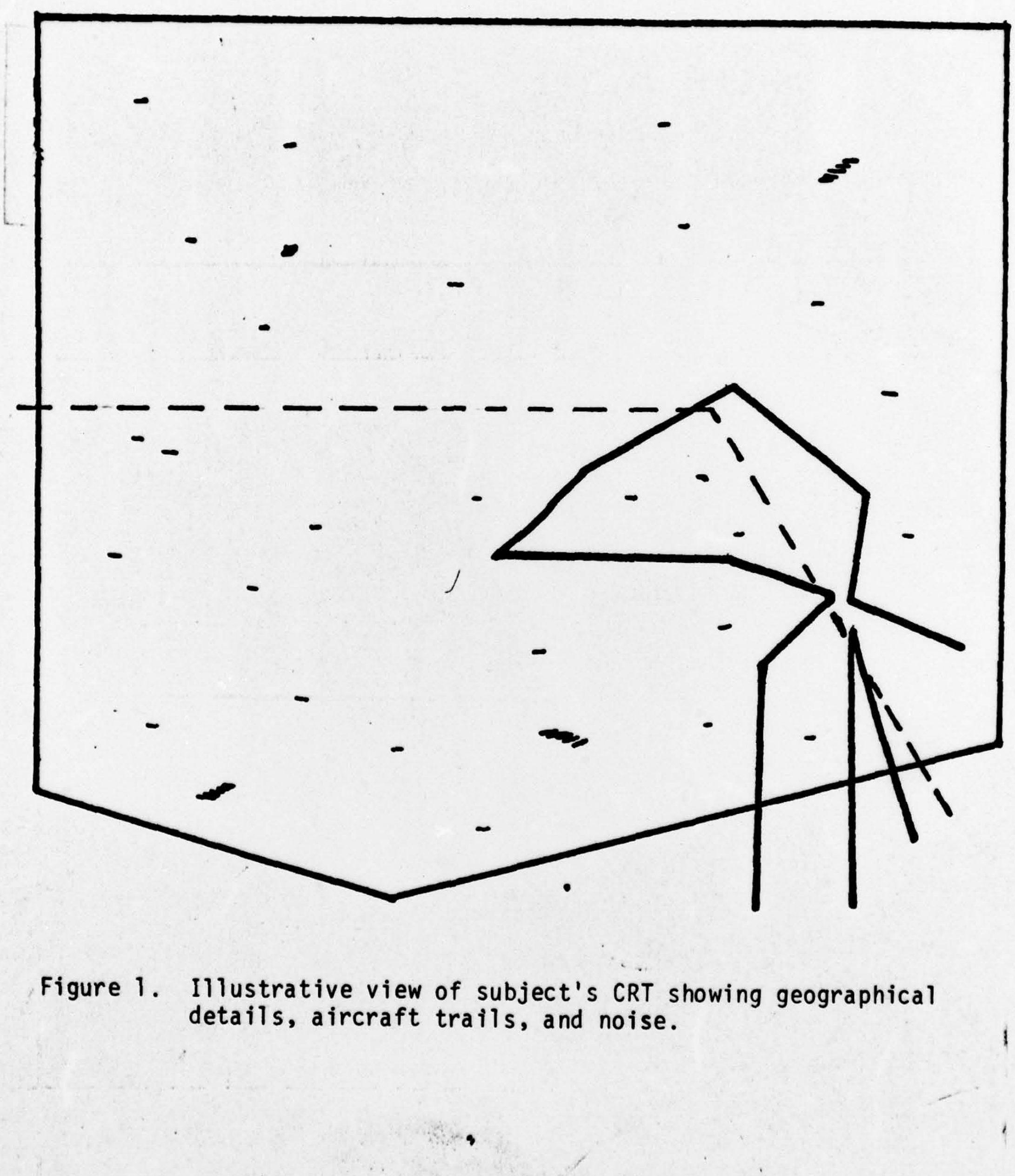


Figure 1. Illustrative view of subject's CRT showing geographical details, aircraft trails, and noise.

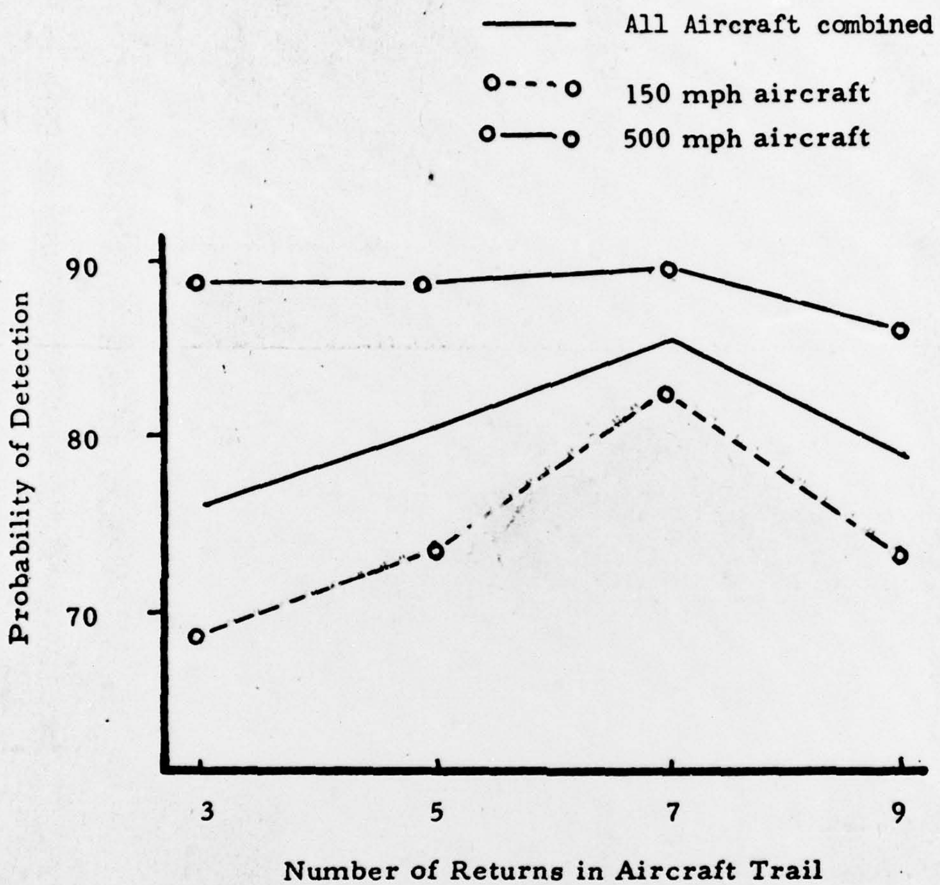


Figure 2. Average track initiation time for aircraft by the various trail lengths.

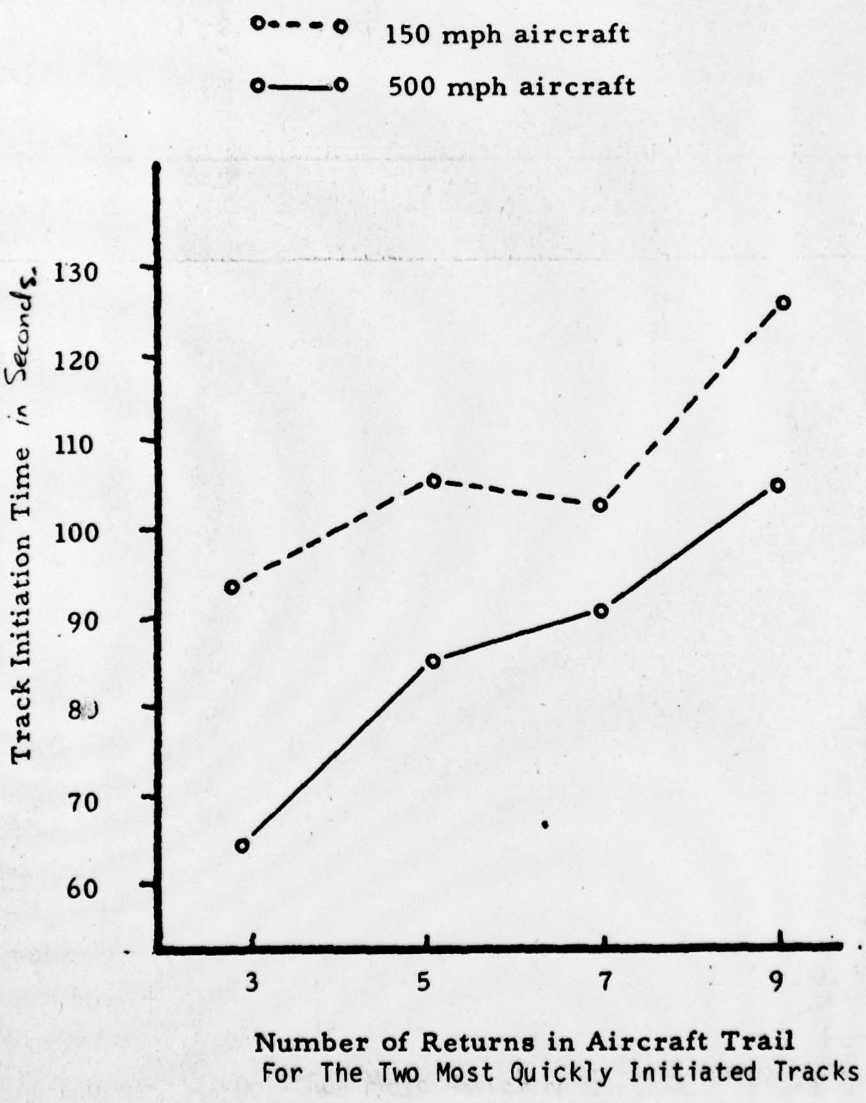


Figure 3. Average probability of detection for aircraft by the trail lengths.

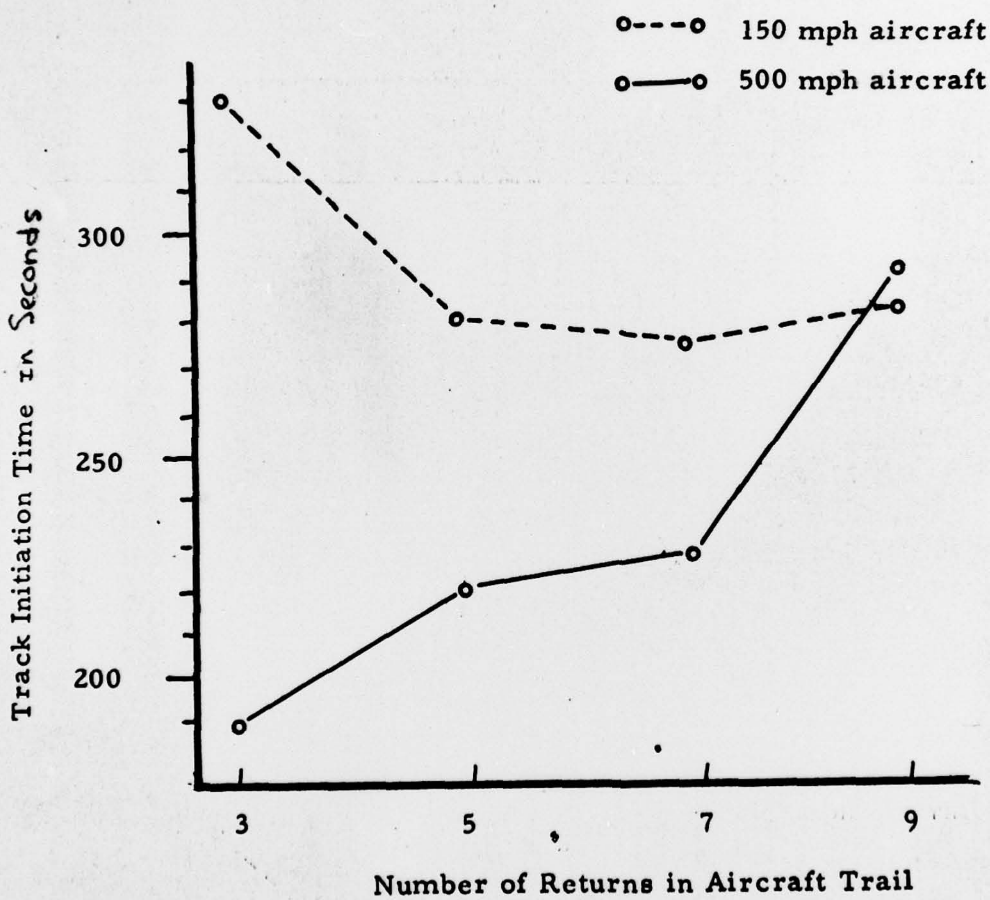


Figure 4. Average track initiation time for two aircraft most quickly initiated by the various trail lengths.

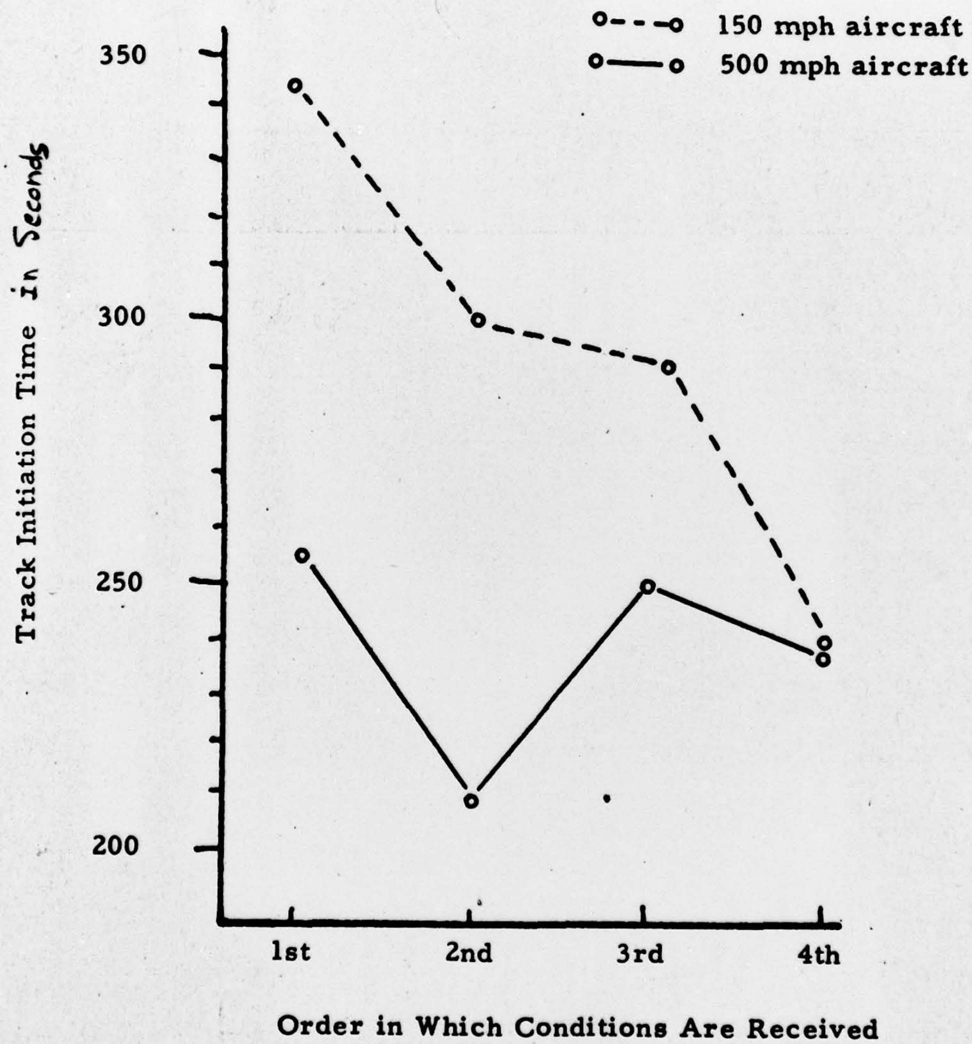


Figure 5. Average track initiation time for aircraft by ordinal day of the experiment.